Virtual Community Heritage

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Virtual Community Heritage – An Immersive Approach to Community Heritage

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Our relationship with cultural heritage has been transformed by digital technologies. Opportunities have emerged to preserve and access cultural heritage material while engaging an audience at both regional and global level. Accessibility of technology has enabled audiences to participate in digital heritage curation process. Participatory practices and co-production methodologies have created new relationships between museums and communities, as they are engaged to become active participants in the co-design and co-creation of heritage material. Audiences are more interested in experiences vs services nowadays and museums and heritage organisations have potential to entertain while providing engaging experiences beyond their physical walls. Mixed reality is an emerging method of engagement that has allowed enhanced interaction beyond traditional 3D visualisation models into fully immersive worlds. There is potential to transport audiences to past worlds that enhance their experience and understanding of cultural heritage.

KEYWORDS

Virtual reality, 3D reality-based modelling, 3D Reconstruction, Immersive Experience, Visualisation, Built Heritage, Community, Co-production

INTRODUCTION

This work is intended to provide an overview of digital heritage and the potential for small heritage organisations to work with emerging immersive technologies to engage communities and visitors. The content within provides background and context to the current state of digital heritage and museum practice, used to demonstrate how collaboration with communities can enhance the development of virtual heritage experiences. We will also outline current mixed reality paradigms (MR) and how this applies to digital heritage to show the potential for enhancing the experience of cultural heritage (CR) and providing new interpretations and immersive visualisations of the past. The example of 'St Catherine's VR', developed as part of the CINE project, is used as a case study to demonstrate the design of a community co-produced virtual heritage experience, the use of technology and how it is received within a museum context.

CULTURAL HERITAGE IN THE DIGITAL AGE

Cultural heritage is a term which describes what humanity, at present has acquired and preserved from the past societies. The acquired heritage can be artefacts, buildings, books, monuments and sites, even old traditions and folklore. This entire heritage needs to be preserved, reconstructed, represented and communicated to people. Digital technologies are critical to the passage of cultural heritage in the modern age by enabling methods of archiving and access. Mixed reality technology is one set of tools that can be used to achieve these aims while delivering new interpre-

tations and cultural heritage learnings.

New digital technologies and the internet have transformed our relationship with cultural heritage. Unprecedented opportunities have emerged to access cultural material, while the institutions can reach out to broader audiences, engage new users and develop creative, accessible content for leisure and education. New technologies bring cultural heritage sites back to life ("Digital cultural heritage | Shaping Europe's digital future," n.d.). Virtual Museums and online archives offer visitors the possibility to view cultural material residing in different places and experience objects or sites otherwise inaccessible. Broken artefacts and site remains can be reconstructed and assembled virtually. Immersive or augmented visitor experiences are more available with emerging tools and interactive paradigms. Location and geospatial data has gained additional significance. Educational courses in virtual sites are provided to students in fields relative to cultural heritage. Digital materials include texts, databases, still and moving images, audio, graphics, software, and web pages, among a wide and growing range of formats. Many of these digital objects are ephemeral, and require purposeful production, maintenance and management to be retained. Many of these resources have lasting value and significance, and therefore constitute a heritage that should be protected and preserved for current and future generations. This heritage may exist in any language, in any part of the world, and in any area of human knowledge or expression.

CONTEXT, ACCESSIBILITY & CURATION

Using computers and related tools, humans are creating and sharing digital resources. Information, creative expressions, ideas, and knowledge are encoded for computer processing. These resources are valued, shared and accessed with others over time. This is evidence of a digital heritage. It is a heritage made of many parts, sharing many common characteristics, and subject to many common threats.

Definitions of heritage need to be seen in context. For example, UNESCO defines a world heritage made up of globally outstanding sites of cultural and natural value that should be preserved; many national and state legislatures also define their own national, regional or state heritage ("Concept of Digital Heritage," n.d.). However, heritage value may also be based on what is important at a group or community level. Heritage materials can exist well beyond the limits suggested by national legislation or international conventions. Anything that is considered important enough to be passed to the future can be considered to have heritage value of some kind.

Heritage can be viewed as a product of selection by society, whether at a macro scale of national, international and global level or at a micro scale of region, locality, right down to community or local interest group level.

This digital heritage is likely to become more important and more widespread over time. Increasingly, individuals, organisations and communities are using digital technologies to document and express what they value and what they want to pass on to future generations. New forms of expression and communication have emerged that did not exist previously. The Internet is one vast example of this phenomenon.

It is also likely that the development of tools to support greater multi-lingual and multi-script use of the Internet will lead to further rapid growth in digital heritage in parts of the world that are currently disadvantaged by the predominant use of English on the Internet.

Making sure this burgeoning digital heritage remains available is thus a global issue relevant to all countries and communities. It is vital to empower communities with the tools, literacy and knowledge to access, document, preserve, curate and share their heritage.

CO-PRODUCTION AND PARTICIPATORY PRACTICE

As communities are empowered to manage and

curate their own heritage the role of the museum is increasingly one of facilitator of community needs.

At one level, participation simply means people being able to make their mark when they visit a museum: to leave a comment, contribute an idea or memory, or to dialogue with someone. Giving people a more engaged experience will make their visit more enjoyable; increasing the likelihood that they will learn and remember more.

In many places, participation goes much further. It can extend to co-curation of exhibitions and even to involvement in decision-making. This has many advantages in breaking down barriers, giving communities an active role, insuring relevance and invigorating museum practice ("Read Online – The Participatory Museum," n.d.); but there are risks in undertaking participatory work. Museums are generally viewed as reliable and trustworthy so there is a need to reconcile co-production with the public expectation that museums are authoritative places for learning.

A key risk factor is that working with a particular group can end up in a soppy celebration of that group's interests or can become a presentation of the group's viewpoint on a particular subject. A group or community may hold a controversial view or unreliable information. Museums 2020 says: "It can require considerable thought and determination when, for example, co-producers can't seemingly co-exist, or when there are several versions of the truth within a locality." (Museums Association, 2012)

In general, the benefits of co-production are to produce richer content with diversity of voices, facilitate the learning of new skills and give greater ownership of the museum or exhibition to its constituents. There are challenges of diminished control, additional management and organisational aspects to consider as a facilitator or heritage organisation.

Co-production is regarded as a vital aspect of museum practice due to the principle advantage of creating actively engaged participants by removing the barriers between visitors and facilitators. It is from this perspective that we approach the St. Catherine's site co-production and St. Catherine's Virtual Reality exhibition. Community co-production would underpin the research and development of the content used to create the experience.

VIRTUAL HERITAGE ECONOMY – EXPERIENCES VS SERVICES

Traditionally, applications of digital heritage were utilised in service of heritage related disciplines such as archaeology. Digital heritage multimedia is essentially used for archiving, preservation and visualisation. In the museum context where engagement of visitors is a goal of the institution, digital heritage has become an integral part of the exhibits and displays. Museums are now finding their futures are aligned with offering visitor experiences that move beyond traditional multimedia and the trend in visitor numbers is aligned to attending for a novel experience. Spatially aware mobile computing, advancements in computer vision and mixed reality hardware along with enhanced interaction methods has provided accessible pathways for museums and exhibitions of all scales to offer immersive visitor experiences. The success of this approach, in terms of feedback and visitor numbers can be traced to the recent evolution of contemporary western societies, in which the socio-economic focus has shifted from providing services to providing experiences (Gentile, Spiller, & Noci, 2007) (Pine & Gilmore, 2013).

For museums or heritage organisations we can refer to this not as location-based experience but experience at a location. Immersive visitor experiences are gaining popularity with investment across a wide range of activities. Many high-end VR units are still above the average consumer's price point, contributing to the popularity of VR centres and arcades across the UK. Government and industry funding has also helped to bring gallery and museum exhibits to life through new digital experiences. In 2018, over 50 locations and 40 operators were identified across the UK alone, while smaller independent locations

are reported to be flourishing and establishing themselves (Catapult & Uk, 2019).

John Cassy, Chief Executive Officer of Factory 42, which produced 'Hold the World', a behind-the scenes tour of the Natural History Museum guided by Sir David Attenborough, says: "By combining world class storytelling with cutting edge immersive tech, we will take people into worlds of enhanced reality that engage their emotions and senses in ways never before possible and that other media simply cannot match. It's an exciting future and the UK, with the incredible pedigree of its creative industries and the right policy and practical support, has every opportunity to lead the world in this space." This trend will likely manifest across nations as digital economies expand and populations trend towards experience and enhanced engagement (Catapult & Uk, 2019).

VIRTUAL REALITY FOR CULTURAL HERITAGE

Virtual reality is a method used to simulate an environment that otherwise is impossible in the real world using various computer technologies in visualiation, sound and interaction. The main goal of this method is to enhance the experience of the person using it and to send the required information in an easy and convenient manner.

In recent years virtual reality has become an accessible form of entertainment due to the ubiquity of smartphone technology such as high-density screens and high-performance mobile processing. Virtual reality is applied across many fields of entertainment, healthcare, engineering, construction, scientific visualisation, training, telecommunications and media applications due to its versatility and modality. One of the core fields exploring the use of virtual reality as a form of visualisation and immersive experience is cultural heritage, allowing users to experience cultural artefacts in a completely new way (Bekele, Town, Pierdicca, Frontoni, & Malinverni, 2018). From displaying a simple environment in stereoscopic 360 degrees to a fully immersive world with high fidelity visualisation, spatial audio, vibrotactile feedback and advanced kinetic interaction methods. Virtual reality offers a broad scope of new paradigms in visualisation, immersion and human centric multimodal experience.

Interest in Virtual Reality has led to increasing experimentation with immersive digital environments and the launch of a number of platforms for VR creation and consumption. These platforms are beginning to be used by historians, archaeologists and curators, often in order to provide a deeper sense of immersion in historical reconstructions (Carrozzino & Bergamasco, 2010).

VR is a complex medium regarding multidimensional approaches and focuses, which also describes a reality (even an alternate reality which has its own rules). Therefore, some factors should be kept in mind, as virtual reality, as an emergent medium, has its own communication and interaction features. These features also have cognitive, technological, design, artistic and agronomical approaches. As an interactive medium, it also has scope to integrate factors such as gameplay.

VIRTUALITY CONTINUUM & MIXED REALITY PARADIGMS

Virtual reality is the de facto term when discussing fully immersive enclosed experiences delivered via a head mounted display (HMD). However, it is important to consider the multitude of paradigms that exist within the mixed reality spectrum, between real and virtual environments. The virtuality continuum was proposed by Milgram and Kishino in the 80s and 90s (Milgram, Paul & Kishino, 1994) as a theoretical approach regarding the connection between information coming from the physical world and artificial

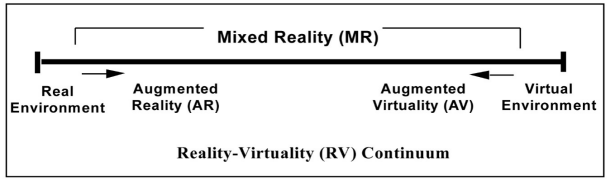

Figure 1. Virtuality Continuum (Milgram and Kishino)

digital information.

Within a heritage or museum context mixed reality systems are utilised to achieve a variety of resulting experiences. Augmented reality can provide on-site visitor experiences that utilise spatially aware devices to augment the real environment, either in an indoor or outdoor context. Virtual reality exhibitions can place visitors within virtual environments to visualise digital interpretations of intangible places or time-periods. Virtual reality can also provide remote access to immersive heritage experiences providing the end-user possesses the required VR hardware.

Based on intended flexibility, Carmigniani et al. (Carmigniani et al., 2011) categorises AR systems into five types: fixed indoor, fixed outdoor, mobile indoor, mobile outdoor, and mobile indoor/outdoor. However, considering AR applications in the Cultural Heritage domain over the past decade, a simpler categorization into indoor and outdoor AR is warranted. Virtual reality systems (VR), on the other hand, can be classified, based on the intended experience, into non immersive, semi-immersive, and fully immersive. These systems are implemented by combining various tracking methods, input devices, displays, and interfaces. Generally, the more enclosed the user is within the experience the more immersive we could describe it. Enclosed is a measure of replacing or augmenting senses and interactions with feedback from

Indoor AR	Indoor AR makes use of either marker-based or markerless tracking, see-through HMDs, spatial or handheld displays, and tangible, collaborative, hybrid or multimodal interfaces. Indoor systems do not need GPS, but if the display is an HMD, then the system might use inertial sensors to track the user's viewpoint.
Outdoor AR	Outdoor AR relies heavily on markerless and hybrid tracking, handheld displays, and tangible interfaces. Optical-see-through HMDs and collaborative interfaces are possible.
Non-immersive VR	Non-immersive systems do not need a pose tracking method at all. The virtual environment is viewed through a desktop or handheld display. Interaction with the virtual environment can occur via device-based interfaces. A sense of presence in such virtual environments is not expected.
Semi-immersive VR	Semi-immersive VR systems are more akin to a flight simulator. They often consist of a large, concave screen, a projection system, and a monitor and are more similar to large screen movie experiences. Semi-immersive systems are a common system in museums, because they can accommodate large number of users simultaneously. Tracking is not required if the experience is intended for multiple users. However, if a single person is using the system, then tracking the user's pose might be useful to correct the perspective of the displayed virtual images.
Fully Immersive VR	Telepresence, which is a state of being fully immersed in a virtual environment, is the ultimate effect of interactive immersion and VR systems that support this are called fully immersive. Immersing users inside a virtual environment is achieved by displaying a virtual scene from the user's perspective on Head Mounted Displays (HMD) or a cave automatic virtual environment (CAVE). The ability to see one's surrounding physical environment is one of the aspects that differentiates AR from VR and in the case of HMDs the user cannot see their own physical body. Natural interaction and being situated inside a virtual environment are the essential aspects of telepresence. Interaction during a fully immersive VR experience is best achieved by employing hybrid and multimodal motion-based interfaces.

Figure 2. Categorisation of Mixed Reality Paradigms

Tangible	A tangible interface affords interaction that exploits direct manipulation of information through physical objects, and AR's ability to combine computer-generated content and physical environments
Collaborative	Collaborative interfaces make use of multiple displays such as see-through HMD to support remote, face-to-face, and shared activities
Device Based	Any interaction interface that uses GUIs, haptic interfaces, and conventional devices, such as mouse, gamepad, joystick, wand, and so on, to allow users to interact with the virtual environment, is defined as a device-based interface.
Sensor Based	In general, sensor-based interfaces employ sensing devices to understand natural interaction modes. The flow of interaction commands is not explicitly forwarded from user to system; rather, the system actively perceives the users' intention through sensors.
Multimodal	A multimodal interface is a fusion of two or more natural interaction modes. Thus, multimodal interfaces use a combination of sensing devices to perceive humans' natural interaction modalities. It is worth distinguishing between multimodal VR experiences and multimodal interfaces. A multimodal VR experience refers to the realism of virtual reality in terms of presence as a result of the effects of the virtual environment on the visual, auditory, and touch senses. Though a multimodal VR experience is implicit in a multimodal interface, the latter refers explicitly to the use of multiple sensors to perceive the commonly used natural interaction modes, such as speech, gaze, and gesture. It is easier to find literatures on multimodal VR than on multimodal interfaces. However, as the technology advances, multimodal interfaces will likely appear in a wider range of domains.

Figure 3. Categorisation of Mixed Reality Interactions

the hardware systems. Visual, auditory, vibrotactile, haptic and kinetic input are general immersive tools within a mixed reality experience.

MIXED REALITY INTERACTION MODELS

As a branch of human centred computing, mixed reality paradigms employ several types of interactions. Screens, devices, haptic controllers and gestures are used to interact with virtual content and environments.

CASE STUDY - ST CATHERINE'S VR

Having established the context for using digital heritage interpretations in conjunction with interactive immersive technology to align with current trends in cultural heritage and participatory museum practice we illustrate this as a practice-based approach. The following sections document the conceptual design, development and evaluation of St Catherine's VR Experience. This work was completed as part of a case study site within the NPA funded CINE project.

ST CATHERINE'S CHURCH & GRAVEYARD

St Catherine's Church and Graveyard forms one of the case study sites within the CINE project and is the subject of the Virtual Reality experience, outlined in this paper. St. Catherine's Church is located in Killybegs, in the North-west of Ireland to the south-west of County Donegal. In the modern age it is an industrialised fishing port due to its natural deep-water bay. The establishment of the settlement dates back to the 14th century with the site of St Catherine's Church being central to the old medieval town and its associated history. Histories that range from the hosting of a Spanish Armada vessel and crew of 'The Girona', piracy and pillaging of the town throughout

the 15th century, the Nine Years War and subsequent 'Flight of the Earls', causing the church to become the property of the protestant Church of Ireland, the 1641 rebellion and relative quiet of the 17th/18th century before falling into disrepair as the focal point of town shifted away from the medieval quarter. The church was abandoned for much of the 20th century and had largely slipped from community memory but the adjacent site of St Catherine's well remained a daily pilgrimage for the town's people. In recent times the Killybegs History and Heritage society have made efforts to preserve the site remains and record the associated history and heritage of the locality. The bulk of these efforts have been in traditional physical preservation of the church and documenting the history in text and image-based formats. This provided an opportunity for the CINE project to apply a digital heritage approach from the perspective of community co-production with a focus on visualising the site in an interactive virtual format.

ST CATHERINE'S PROJECT DEVELOPMENT

A starting point in heritage co-production involves casual meetings, roundtables and discussions of heritage through stories and informal interactions. The goal is not to sway the direction of the project but to facilitate the goals of both the community and organisation:

Figure 4. St Catherine's Site Remains – Physical restorations works have been completed to preserve the site to its current condition along with regular maintenance and ground works.

- Listen to the needs of the community or group.
  - Identify techniques or digital skills that might support the existing work or aims of the group.
- Allow the direction of the Co-production to emerge naturally.
  - Facilitate discussions of which particular aspects of the site are significant to the group or content that should be included.
- Provide resources to support the project.
  - data collection, site mapping and digitisation processes.

Figure 5. Co-Production Site Mapping & Data Gathering – Donegal County Museum, Ulster University researchers, members of the Killybeg's History & Heritage Society and interested members of the local community

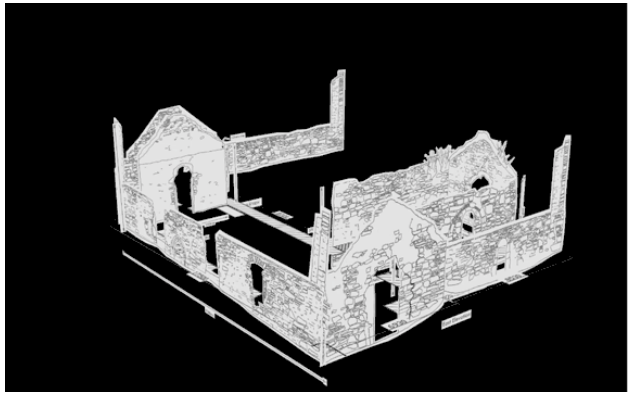

Figure 6. Archaeological Drawings reconstructed as a 3D template for modelling

The practice of developing the St. Catherine's VR project involved multiple discussions with the heritage community to identify how the St Catherine's site would be best represented and interpreted as a digital output, identifying digital tools that would be useful to achieve this and how the community, museum and university could collaborate on collecting the data and mapping the site. The advantage of working in this capacity is that the research and heritage information lives within the community, freeing the facilitator to provide tools and services to document or digitise the artefacts and information. The second stage in this practice was to organise a series of on-site open days where people were invited to participate in the mapping of the site. These events help facilitate discussions, enable learnings for all parties and build a sense of camaraderie.

Once the site was documented, work was undertaken to build a 3D reconstruction of the St Catherine's Church and environment based on the mapping and research of the community. Archaeological plans from the site maintenance efforts had been made available by the heritage society. These were used to base the reconstruction on and ensure the church model was a build on a 1:1 scale to the actual environment. Each grave had been mapped and drawn into the archaeological plans to allow an exact 3D representation of the surrounding environment. Images and textures were taken from the site to base the reconstruction and texture mapping upon. Due to the archaeological mapping, enough information was available to reconstruct the environment negating the need for aerial drone scans or lidar techniques. Photogrammetry was employed to capture key graves and legible markers in the environment. These objects would be processed and positioned at the corresponding location within the 3D reconstruction. As the site only contained the remains of the church walls some guesswork was required as to how the roof and extended structure would be represented in the reconstruction. This also applied to how the inside of the church would appear regarding the layout of

Figure 7. St Catherine's Church 3D Reconstruction

the altar and internal objects. Where the information was not available or apparent the lead would be taken from how the community group imagined the site in its past instance.

An example of this practice is in the placement of the baptismal font within the church reconstruction. The stone font had been removed from the church sometime in the 18th century and placed in another active church nearby. An objective of the co-production was to capture this object and place it back in the virtual environment as a way of reuniting the object with its original home in a virtual context. The font was digitised via photogrammetry, retopologised and placed in the reconstruction at a position where the community members agree it may have been originally located. This process allowed for the community to be involved in the idea generation, digitalization process and throughout the design and development process.

ST CATHERINE'S VIRTUAL REALITY (DESIGN CONCEPT & GOALS)

St Catherine's VR is designed as a visitor experience using enclosed standalone virtual reality with kinetic movement via motion-based haptic interactions.

The objectives of the project:

- Gather a collection of digitised artefacts and heritage objects in a range of multimedia formats.
- Create a Virtual Museum to host the collected community heritage.
- Build a 3D Reconstruction of the church and surrounding environment as it was in the 16th century.
- Deploy the project within a Virtual reality framework that allows users to:
  - Visit a Virtual Museum and reconstructed historical environment.
  - Explore and interact with the virtual environment and digitised artefacts.

- Employ basic interactive storytelling or points of interest to provide narrative context for the reconstructed environment.

The project output:

- To run on standalone VR hardware within a museum exhibition space and eventually a visitors centre nearby the St Catherine's site.
- Requires minimal maintenance in day to day running.

Fully immersive Virtual Reality was selected as the delivery method for several reasons. The project would exist in an indoor location that allows space to provide a room-scale experience with only financial limitations on computer processing power. Enhanced interaction would be available through haptic motion controllers allowing users to examine artefacts and explore the environment. The additional technical benefit with standalone VR is in requiring less optimization or downgrading of graphics as typically seen in a mobile or augmented experience.

ST CATHERINE'S VIRTUAL REALITY (FRAMEWORK)

St Catherine's VR is comprised of a dual environment framework composed of a virtual museum and a virtual reconstruction. Users can freely navigate and

Figure 8. St Catherine's VR Virtual Museum – Users can navigate the space and interact with the digitised heritage objects.

Figure 9. St Catherine's VR Virtual Museum – Users can navigate the space and interact with the digitised heritage objects. A lantern can be carried to increase the scenes of exploration and visual aesthetics & atmosphere.

interact within the limits of the virtual space. Navigation, exploration and discovery are encouraged.

The virtual museum is presented as the hub or overworld setting for the virtual reconstruction. Virtual museums simulate and present tangible and intangible cultural heritage in digital museum form (Boyle, 2008). In the St Catherine's application, the virtual museum is akin to a real-world museum. It contains artefacts and contextual information in digital format. Images of the real-world St Catherine's site remains can be viewed along with photogrammetry 3D models and a miniature reconstruction model of the church.

From within the virtual museum users can enter the virtual reconstruction by navigating through a highlighted portal window. Once in the virtual reconstruction the user's attention is directed using contextual points of information taken from community heritage research (Boyle, 2008). Points of interest provide a narrative context using a mixture of stories, mythology, history, folklore and built heritage information. The placement of narrative points within the reconstructed environment are based on relevance within the environment. For example, when the user is by the sea, they can read about the visitation of the Spanish Armada in 1588. Within the church they will read about the built heritage and amendments to the church structure as it passed between Catholic and Protestant faiths in line with the shifting social and religious dynamics of Irish history. The aim is to provide context to the environment and place the scene within the wider context of history.

Teleport	Users can teleport to pre-determined locations in the environments. Pressing the pad or thumb stick of the motion controller creates a visual arc, indicating where users can jump to upon release of the pad. This is a standard movement mechanic in VR to avoid nausea or physical discomfort when using motion-based movement.
Grab	Users can grab objects using natural hand motions with the motion controllers and squeezing the trigger to hold. Grabbing allows users to: • interact with digitised artefacts and examine them in close detail • piece together the architectural model of the church in small scale • hold a lantern while moving through the church reconstruction providing a light source to enhance their exploration
Point	Users can press the left pad to point a laser from their hand/controller. The laser is used to interact with points of information giving context to areas of the environment and general historical information of the real-world's locality.

Figure 10. Micro interactions used in St Catherine's VR

ST CATHERINE'S INTERACTION MODEL

St Catherine's VR allows users to move freely in the virtual environment using haptic controllers on both the Oculus Rift and HTC Vive. Navigation is handled via a teleport mechanic. Object interactions are performed via natural grab and kinematic motions. A laser pointer is also available to interact with contextual information points in the environment. The goal of interactive mechanics in VR, when considering users may be inexperienced with the technology, is to keep it easy to understand and avoid controls that require long adaptation or mastery (Galdieri & Carrozzino, 2019).

ST CATHERINE'S VIRTUAL REALITY – TECHNOLOGY & DEVELOPMENT

St Catherine's VR is developed in Unity Engine. Unity is a proprietary 3D engine that is free to use for non-commercial development. It runs on Windows or OS X and can build applications for each leading VR platform including, Oculus Rift, HTC Vive, Open VR and Google VR. Unity supports advanced lighting, post processing and physically based shaders and rendering technology, allowing for graphical fidelity approaching photorealism.

3D modelling of the church and additional environmental props were completed using 3D Studio Max. Scale provided the biggest challenge in modelling as the reconstruction relies on accuracy of site mapping and architecture. Using the site mapping information and architectural drawings of the church remains it was possible to create a 3D template and model to the exact scale of the real-world environment. The majority of the environment's architectural textures were procedurally generated using Adobe Substance Designer. The environmental vegetation and organic elements were created with a combination of Unity's Terrain Tools and a procedural vegetation generation package, Vegetation Studio.

Specific artefacts, such as gravestones were digitised via Structure From Motion (SFM) or photogrammetry. A series of images of each artefact were captured and processed using Agisoft Photoscan.

Figure 11. Digitisation of site artefacts for the virtual world - Processed using photogrammetry

Enhanced visual fidelity is achieved using post-processing techniques of Bloom, Ambient Occlusion, Colour Correction, Tone Mapping and Anti-Aliasing.

ST CATHERINE'S VR - IN USE

St Catherine's VR has been trialled in a number of contexts with members of the general public within a live museum setting.

Event	Location	Date	Demographics
Heritage Week Ireland	Donegal County Museum	17-25/08/19	Family Groups of all ages (80 visitors/users)
Culture Night	Donegal County Museum	20/09/19	Family Groups of all ages (400 visitors/60 users)
Visiting School Groups	Donegal County Museum	23/10/19	School groups aged 14-16 (80 visitors/users)

Figure 12. St Catherine's VR exhibitions – The virtual exhibit was used to promote events and test with target groups during the trial phase

EVALUATION & FEEDBACK

Evaluation and feedback has been gathered via a validated qualitative questionnaire (igroup presence questionnaire (IPQ)) ("igroup presence questionnaire (IPQ) overview | igroup.org – project consortium," n.d.) to assess the following three catagories:

1. Spatial Presence - the sense of being physically present in the virtual environment.
2. Involvement - measuring the attention devoted to the virtual environment and the involvement experienced.
3. Experienced Realism - measuring the subjective experience of realism in the virtual environment.

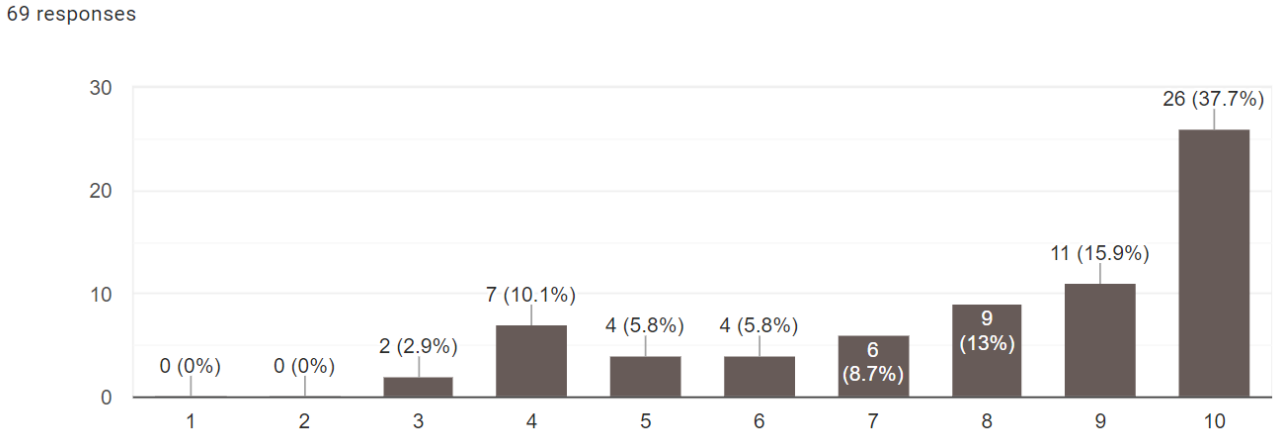

Figure 13. Results of the survey to determine the overall level of presence for a cohort of users within the virtual environment

14 questions were asked on a scale of 1-10 with 1 being 'completely disagree' and 10 being 'completely agree'. The mean average of this assessment is calculated to determine the general "sense of being there". We can equate this to a successful exhibit when presenting a virtual reality reconstruction.

Completion of the survey was optional via pen & paper or through a Google webform.

69 responses were collected from school groups of 14-16 year olds. A 37% majority felt fully present overall in the experience with the other scores relatively evenly distributed along the scale. None of the participants felt no sense of presence. A limitation of this evaluation is that it was conducted in a live environment so external pressures and factors were in effect. There is also the intangible 'novelty of technology' factor to consider, in that excitement tends to be higher with first time or new users of VR. This factor was evaluated within the responses by asking the number of times participants had used some form of virtual reality. From this cohort, the majority were first time users or had tried under 10 times. Only 10% could be considered experienced users.

Further visual analysis has been conducted directly in the Unity engine by capturing user navigation actions within the virtual environments. Posi-

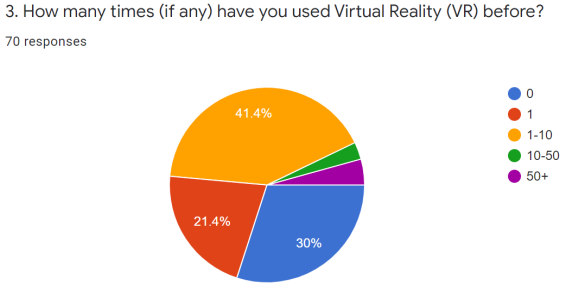

Figure 14. Breakdown of previous experience using some form of virtual reality

tions have been logged and rendered as heatmaps using a custom developed data collection and visualisation system. Using this system we are able to visually determine how users navigate the environment and determine points of interest that receive the most attention. Further to this we can map the user movements within the virtual environment to the real-world environment to inform how a potential visitor site experience could be constructed.

Figure 15. Heatmaps rendered in the virtual museum and virtual reconstruction showing where users moved and spent most time

CONCLUSION & FUTURE WORK

Digital heritage is trending to provide new levels of user experience as advances in technology enable providers to create or commission immersive worlds, accessed via multimodal VR systems. Visitors can be engaged via immersive exhibits that offer new paradigms in telepresence within imagined realities, derived from heritage research and preservation. Hardware is becoming more accessible to the point that immersive experiences can be achieved by smaller, local and regional organisations within their exhibits or practice.

It is essential for heritage organisations to engage with communities to forge new collaborative relationships via co-production and participatory practice. By utilising this practice, museums can produce richer content through diversity of voices and engage the local community as active curators, makers and documentarians of their cultural heritage. Co-production practice is also possible within the development of a virtual exhibit and working with a community benefits both parties in achieving their respective goals.

3D reconstructions and photogrammetry are standard tools within digital heritage but also provide additional benefit in creation of virtual explorable environments. Immersive hardware and falling costs in the development of virtual environments have made it possible to achieve fully immersive experiences at small scale that can have a large impact on visitor numbers and engagement for an organisation.

There is inherent potential for heritage sector organisations to employ innovative digital heritage practices or consider new digital strategies. Collection and digitalization are essential practices to providing remote access to cultural heritage and also developing virtual visitor experiences. Collected digital objects can be used to construct a number of outputs from 360 photosphere tours, augmented reality paradigms to fully immersive virtual reality experiences.

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